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EDITOR, C. A. CHANT ASSISTANT EDITOR, F. S. HOGG

David Dunlap Observatory
Richmond Hill P.O., Ont.

ASSOCIATE EDITORS

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Ottawa

J. A. PEARCE
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J. PATTERSON
Controller of the Meteorological Service of Canada, Toronto

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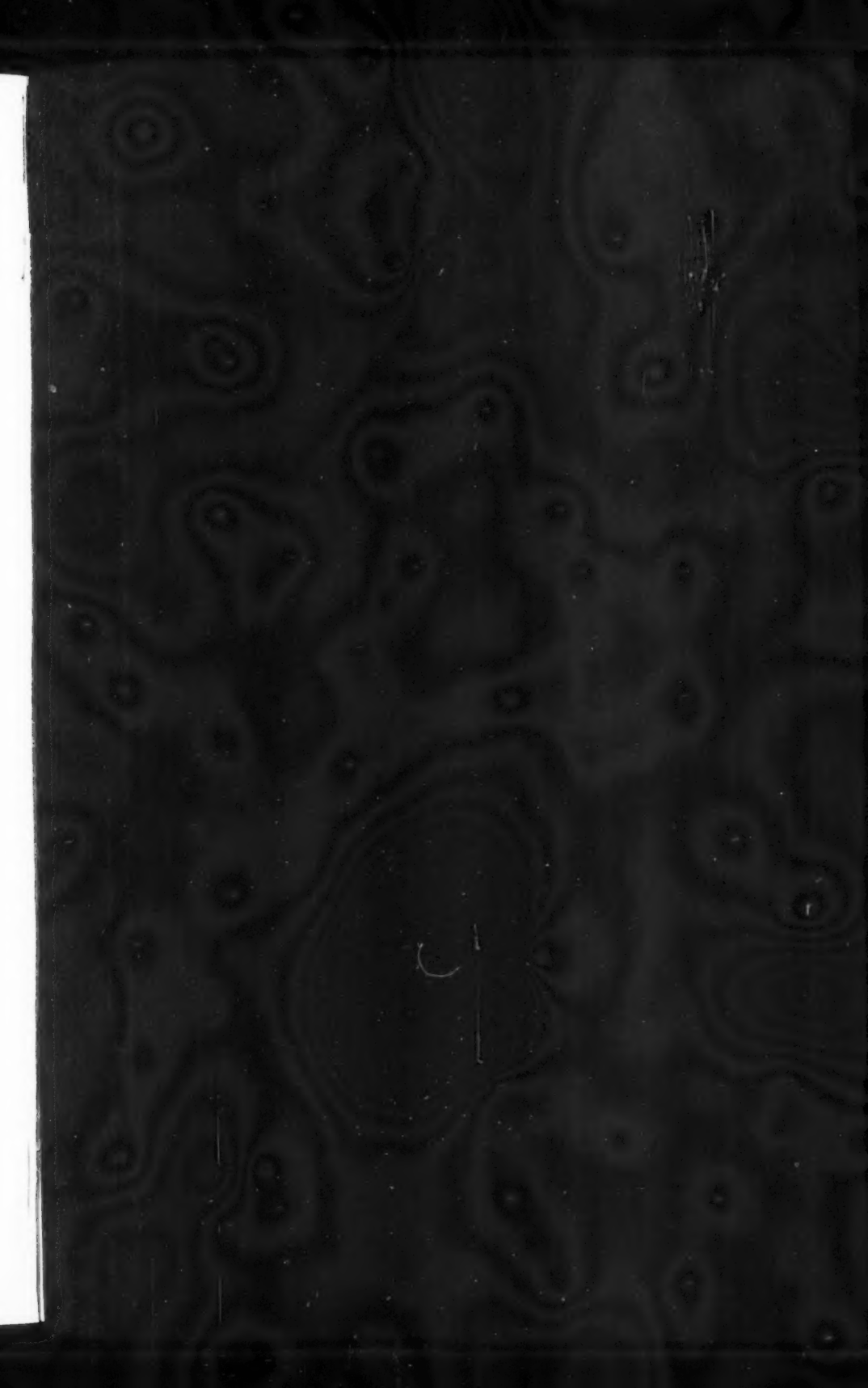

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RESEARCH AT MOUNT WILSON OBSERVATORY*

By WALTER S. ADAMS

ALTHOUGH somewhat handicapped by the stormiest winter in the history of the Observatory, the scientific work has been continued actively, and interesting results have been obtained in several of the major fields of investigation. The sunspot maximum is well past, but spots are still numerous and studies of their magnetic fields, of the character and motions of eruptive prominences, and of solar outbursts and other phenomena related to the sun's activity have formed an important part of the observational programme. A new polarizing monochromator built up of a series of quartz plates has proved most efficient for many of these observations. Especially interesting is the additional evidence that the motion of eruptive prominences changes not uniformly but by a set of abrupt transitions in which there may be an integral numerical relation between successive steps. One of the largest solar prominences ever photographed, extending outward from the edge of the sun to a distance of 500,000 km., provided some of the data for this investigation.

It is well known that the magnetic field of the earth is subject to fluctuations in a period of 27 days, the rotation period of the sun. To account for this effect the hypothesis has been proposed that certain areas on the sun are the source of charged particles affecting the earth's field. An attempt to identify these hypothetical areas with those covered by calcium clouds (flocculi) on the sun shows a considerable degree of agreement, although some prominent cases are discordant. The problem is of sufficient interest to warrant additional study.

In the field of stellar distances and motions, measurements of position have yielded distances for several close neighbours of the sun,

*Extracts from the Annual Report of the Director of Mount Wilson Observatory for the year 1940-41.

including one star whose intrinsic brightness is about one-fifty-thousandth that of the sun. Nearly 30 new members of the Pleiades cluster have been discovered, a result of particular interest as bearing on the question of the relative numbers of stars of different luminosities.

* * *

In the broad field of stellar spectroscopy, investigations have been numerous and varied. The need for observing fainter and fainter stars or for applying higher dispersion to the brighter stars has required the use of every possible means for economizing light and utilizing it most effectively. This has affected the design of spectographs and has led to such improvements as the "image slicer" invented by Dr. Bowen, of the California Institute of Technology, non-reflecting thin films on the surfaces of lenses and prisms, and bright gratings and Schmidt cameras. The general result has been a marked gain in efficiency and the possibility of observing stars previously beyond reach.

Variable stars of different classes have long been objects for intensive spectroscopic study at Mount Wilson. An important research on about 300 stars of the long-period class has recently been completed and the results have been analysed. The residual radial velocities are found to be exceptionally high and to exhibit a group motion in a direction opposite to that of the galactic rotation of the solar group of stars. A well marked relation is found to exist between velocity and period of light-variation—another illustration of the remarkable connection between the physical properties of stars and their motions which is as yet quite without explanation.

Related to the previous investigation is a study of the spectra of more than 100 M-type stars of irregular light-variation but without emission lines. They show large residual radial motions, little concentration toward the galaxy, and but slight variation of velocity with change of light. Their luminosities approximate those of the normal long-period variables.

Physical studies of the spectra of variable stars of different classes have led to the discovery of some remarkable peculiarities in individual stars. The presence of emission lines of calcium in one or two eclipsing variables and the differences in radial velocity indicated by these lines suggest the presence of calcium envelopes about these systems. Further observations of two of the brighter Cepheid vari-

ables with exceptionally high dispersion confirm the anomalous behaviour of the H and K lines of calcium previously discovered and show marked differences in the behaviour and displacement of several absorption lines dependent upon the phase of light. The striking irregularities in the intensities of certain members of the emission lines of hydrogen in long-period variable stars find a probable explanation in the hypothesis that such lines are produced at a low level in the stellar atmospheres and are affected by the absorption of overlying gases. All these observations and many others emphasize the necessity for analysing the atmospheres of giant stars according to level and even considering the influence of semi-detached envelopes or shells surrounding the stars.

* * *

Several of the investigations of the year on nebulae within our galaxy have dealt with nebulous shells about novae. One of these, around Nova Aquilae 1918, is 45″ in diameter but very faint. Observations made since 1922 can be represented by the expansion, at a rate constant since the outburst, of a single shell of considerable thickness. The distance of the star derived from the rate of expansion and the radial motions is about 1400 light-years. Nova Herculis 1934 has also been observed spectroscopically. The star is involved in a small bright elliptical shell which shows complex emission lines. The rate of expansion, if the separation of the lines is due to Doppler effect, is about 300 km./sec.

A most interesting discovery is that of a small fan-shaped nebula within 1′ of the position of the bright nova of 1604 (Kepler's Nova). It was found on red-sensitive plates and is extremely faint in blue light, probably because of strong space absorption in this region. Kepler's estimates of brightness follow closely the normal light-curve of one class of supernovae, and it appears highly probable that the nebula forms the remnant of a supernova in which the range in brightness exceeded 20 magnitudes. This would make the third supernova in the galactic system within the past 900 years.

The Crab nebula, believed to be the remnant of the supernova of 1054, is found to consist of two kinds of nebulosity, one which is diffuse in character, forming the main mass, and the other of filamentary structure, surrounding this mass. The spectrum of the diffuse nebulosity is purely continuous, whereas that of the filaments consists of emission lines. The emission spectrum may be due to

excitation by the continuous spectrum of the diffuse nebulosity, but the source of the continuous spectrum itself is wholly uncertain.

One of the very important but at the same time difficult questions relating to extra-galactic nebulae is the direction of motion of the arms in spirals. Observations made during the year show definitely that in two spirals the arms are trailing as the nebulae rotate. The fact that the direction of rotation with respect to the spiral patterns is the same for the 10 nebulae for which data are available makes it at least probable that the arms are trailing in all spirals.

* * *

Definitive light-curves have been determined for several supernovae. Those for stars of spectral group I are very homogeneous, becoming linear about 100 days after maximum of light. The curves for stars of group II show occasional halts on the descending branch and may in several respects differ considerably one from another. The absolute photographic magnitudes of the two groups at maximum of light are, respectively, –14.05 and –11.8 (upper limit). The available data suggest that the frequency of stars of group II may be six times that of group I. Whether the group II stars form a physical group separate from normal novae is as yet uncertain.

* * *

The usual method of testing parabolic mirrors during figuring requires the use of a plane mirror with a radius considerably more than one-half that of the mirror to be tested. For very large mirrors this becomes a serious consideration. To avoid the necessity of figuring a plane mirror some 10 feet in diameter to test the 200-inch mirror, Anderson and Ross have devised a method which utilizes the centre of curvature of the mirror to be tested instead of its focus. A simple lens, 10 inches in diameter, with a rather large constant of spherical aberration, is placed on the axis of the 200-inch mirror about 60 inches inside the center of curvature. The lens and a slightly deformed correcting plate used with it are so figured that their combination insures exact coincidence of a monochromatic image from any zone of the lens with the intersection of the normals to the corresponding zone of the mirror. Imperfections in the surface of the mirror may then be detected by the usual knife-edge test. One great advantage of the method is that the entire surface of the mirror is visible throughout the test.

DOES ANYTHING EVER HAPPEN ON THE MOON?

By Walter H. Haas

Continued from page 376

Possible Lunar Meteor*

The observation about to be reported is so surprising that it is likely to impress many conservative minds as ridiculous, but I do not wish on that account to suppress anything that may advance knowledge of the moon.

On July 10, 1941, I was observing the nearly full moon with a 6-inch reflector at 96×, the seeing and the transparency both being 4. At 5^h44^m, while drawing the crater Hansteen, I saw a tiny luminous speck move across the moon's surface at a uniform rate. It appeared about one north-south diameter of Gassendi west of that crater and travelled almost due east until it vanished just short of Gassendi's west wall. The speck was far smaller than any of the central peaks of Gassendi, and it is thought that the angular diameter could not have exceeded 0″.1. The brightness was constant along the whole path, and the stellar magnitude was estimated to be +8. The duration was about one second.

Near 5^h41^m I had seen a fainter speck somewhere south of Grimaldi but only by vision so indirect that little more would have been thought about the matter if the second speck had not soon appeared.

The end-points of the motion of the well-seen speck were *strikingly definite*; and we may accordingly exclude as the cause of the appearance any terrestrial object low in the atmosphere (e.g., thistle-down), for it would have moved all the way across the field of view. One thinks next of a telescopic shooting star very near its radiant. But since I have on no other occasion seen similar specks and know of no such observations by others, it is apparently very difficult to see shooting stars against the moon; and one is justified in giving some figures based on the assumption that the speck was a *lunar* meteor.

*This section was inserted after the rest of the paper had been completed.

An angular diameter of 0″.1 would mean a linear diameter of about 600 feet, a value similar to the observed sizes of terrestrial fireballs. As seen from the surface of the moon the stellar magnitude would have been $8-16.6=-9$ (roughly). On Plate 14B in Pickering's Atlas[53, 54] I measured the length of the projected path to be 63 miles, a value probably not in error by more than 10 miles. The corresponding velocity *relative to the moon* was at least 63 miles a second, the exact value depending upon the undeterminable orientation of the real path in space; but the velocity is in any case surprisingly large, the more so when we bear in mind that the meteorite, which moved eastward, overtook the moon.

Lunar Eclipses

The rapid and extreme temperature-changes of the moon's surface during lunar eclipses[44, 74] might produce observable effects upon varying areas due to *real changes* but could not influence those due to incident light. I shall here summarize observations so far undertaken to detect such possible effects:

1. *December 27, 1898.*[48] Pickering found that the eclipse did not alter the Riccioli dark area, the Alphonsus dark spots, the Olbers dark spot, Schroeter's Valley, Pytheas, or a craterlet in Serenitatis; he was uncertain about possible effects on a dark area west of Webb and on the size of the Linné spot. Douglass measured Linné to be enlarged by 0″.5 for perhaps 30 minutes after it had re-entered sunlight.

2. *December 16, 1899.*[49] Pickering found no effect on Schroeter's Valley, the Riccioli dark area, or the Webb dark area but noted a possible enlargement of Linné by 0″.14.

3. *October 16, 1902.*[45] Linné was so strikingly enlarged that Pickering doubted its identity when it first emerged from the umbra. The amount was 2″.75, and there was no decrease in size for 45 minutes after the shadow had left.

4. *April 11, 1903.* Pickering observed Linné to be enlarged by 0″.55, but 0″.35 of this amount was gone 75 minutes after emersion.[52] Saunder obtained an enlargement of 0″.4 or 0″.5.[53, 56] Wirtz observed a similar increase and further found the spot growing rapidly larger before the shadow covered it.[56]

5. *August 14, 1905.* Linné did not enter the umbra, but Wirtz reported "an increase in the size of the spot up to the maximum obscuration amounting to 1″.24."[56]

6. *February 8, 1906.* Frost and Stebbins agreed that the eclipse enlarged Linné by about 1″.[56]

7. *1906-35.* Pickering observed a number of eclipses in this period, and the results are scattered throughout his lunar papers. I found upon studying

his ***original records*** that most areas where he suspected real changes were unaffected and that the green on the Grimaldi floor was sometimes influenced.

8. *July 16, 1935.* Handicapped by lack of experience and a thick haze near the end of totality, I perceived no effects on Plinius, Aristarchus, Grimaldi, or the Theophilus peaks.[25] Linné was perhaps enlarged by about 1″.5. The south tip of the Riccioli dark area was invisible when it re-entered sunlight and was first remarked two hours later.

Wilson kindly submitted a good set of photographs of this eclipse taken by the De Witts in Nashville, Tennessee, with a 12-inch reflector. A careful study of them to find possible effects revealed a probable lightening of the Grimaldi floor, a possible fading out of the south tip of the Riccioli area for at most 80 minutes, a possible enlargement of Linné, and no effect on Eratosthenes or the Webb dark area.[27]

Miller, Beede, and Buchanan reported that "none of the craters or spots seemed to change," but minor alterations might have escaped their notice.

9. *May 14, 1938.* McLeod observed that the south tip of the Riccioli area faded out completely and was still absent 30 minutes after re-entering sunlight.[25] In a private letter written on June 7, 1938, he declared: "There is no doubt but that the southern tip of the spot had vanished after totality."

10. *November 7-8, 1938.* Visual observations were made by Johnson; by Chase, Miller, Bachner, Shaner, and Grandmontagne, all at one station; and by me; and photographs were taken by Smith and at the Naval Observatory. The moon rose eclipsed, and haze and bad seeing prevented any visual observer from having a satisfactory view of any lunar object before it was an hour out of the umbra.

Riccioli entered sunlight at about 23^h10^m on November 7. Five Naval Observatory photographs during the following hour, and three by Smith between 0^h33^m and 0^h58^m on November 8 *suggest* that the south tip of the dark area was then somewhat lighter than usual. At 0^h52^m and at 1^h20^m Smith thought Riccioli normal. At 0^h5^m it appeared normal to me; at 1^h5^m and at 1^h50^m I suspected that the south tip was lengthening. Micrometric measures I made indicated that the spot lengthened by 4″.4 between 0^h10^m and 2^h30^m.[25] Johnson *suspected* the south tip to be blunted at 1^h55^m but considered it to be normal at 2^h20^m. Apparently the south tip was only slightly lightened and shortened at this eclipse.

Grimaldi emerged from shadow at about 23^h10^m on November 7. Eight photographs between 23^h11^m and 0^h58^m on November 8 show the south half of Grimaldi much darker than Oceanus Procellarum. This appearance was striking to the five Youngstown observers near 1^h0^m; and Chase wrote me: "While the moon was in the penumbra (before 1^h14^m) Grimaldi was the darkest patch on the moon. . . . Everyone agreed that there was not the faintest touch of green [to Grimaldi], instead everything was dark brown . . . like the colour of well-cured tobacco leaves." At 1^h15^m all five observers noted that Grimaldi was now only as dark as Procellarum. A lightening of the crater appears more likely than a darkening of the *mare*.

Linné left the umbra near 23^h40^m and, according to my micrometric measures, shrunk 0".8 between 0^h35^m and 2^h5^m.[25]

Eratosthenes was in sunlight after about 23^h30^m. The Naval Observatory photographs indicate that at 0^h0^m the intensity of the dark areas in the east half of this crater was about 2.5 (midway between Imbrium and the Alphonsus spots). Johnson thought these areas 3.0 to 3.5 at 2^h32^m, 2.5 to 3.0 at 3^h1^m, and 2.0 to 3.0 at 6^h22^m but had a much clearer sky for the third observation than for the other two. Any change is doubtful.

Ball detected no effects on "areas where traces of vegetation had been suspected."[73]

11. *October 28, 1939.* Barcroft, Beamer, Houston, Johnson, Smith, and Vaughn observed this eclipse.

Aristarchus, Macrobius, Messier, and Pickering showed no effects.[27] Vaughn suspected a brief darkening of the two largest dark areas in Schickard, but evidence is unsatisfactory.[27] Smith *suspected* that Grimaldi was darkened slightly but four others found no effect.[27]

Riccioli left the umbra at 7^h9^m. Before 7^h15^m Johnson noted that the dark area was normal. Houston found the south tip to be fading at 4^h50^m (immersion at 5^h3^m) and could not see it at all at some time between 7^h9^m and 8^h18^m. Beamer thought that a lobe developed on the southeast side of the dark area between 7^h20^m and 7^h55^m. Smith, Barcroft, and Vaughn observed no changes in Riccioli. Houston considers the fading real and attributes its escaping the others to lack of contrast with their relatively high magnifications;[27] but drawings submitted by the various observers show that Johnson had much the most distinct view, and any change hence appears doubtful.

Eratosthenes came into sunlight at 7^h40^m. Near 8^h0^m Smith and Johnson both suspected that the dark areas in the east part of the floor were darker than before the eclipse. The former at 8^h50^m and the latter at 9^h20^m considered these areas about normal again. Johnson later wrote that he had compared them to the surrounding *maria* and that he estimated the extent of the abnormal darkening to be between 0.5 and 1.0 units of intensity.

A post-eclipse sequence of photographs by Smith, *begun at* 8^h40^m, reveals no changes in any object. The only thing of interest as a possible alteration on a sequence of Griffith Observatory photographs[18] is that Linné was probably larger near 8^h45^m than before the eclipse (I did not examine the rather poor published reproductions).[18]

Our studies of lunar eclipses support three conclusions:[25, 27]

1. It is highly probable that eclipses do produce some changes, some arrests and reversals of normal developments.

2. Most areas, even those exhibiting periodical changes, are not affected to an observable extent; and all effects produced are slight and last only a short time—probably never as long as three hours.

3. The same object may be differently affected at different eclipses (compare the 1899 and 1902 results on Linné).

Fauth considered the eclipse-enlargement of Linné an illusion due to the temporary dazzling of the eye by the moon emerging from eclipse,[12] but this

argument loses all force when one recalls that Linné is near the centre of the moon so that the eye has already been viewing uneclipsed regions for 30 minutes, more or less, when Linné leaves the umbra and that the "temporary" dazzling must last as long as 75 minutes (refer to descriptions above).

Wirtz more plausibly suggested that Linné appears larger when less well illuminated in the penumbra.[56] His explanation requires that the spot be the same size at equal intervals before immersion and after emersion. Such a condition was found by Wirtz in 1903 and by Frost in 1906, but it is contradicted by the results of Pickering in 1902 and Stebbins in 1906.[56] Experiments convinced Pickering that the spurious enlarging of Linné due to lessened light in the penumbra is far less than the measured change.[56]

John Herschel's lucid geometrical discussion of colours on the eclipsed moon deserves passing mention.[30]

Irregular Changes

If lunar changes are due merely to varying illumination, then an object must always present the same appearance at the same colongitude in different lunations except for such variations as differences in libration and the sun's selenographic latitude may introduce; but if real changes are the cause, then we may axpect some additional small differences from one lunation to another. A number of such irregular changes discovered by ourselves and by others have already been described, and it is significant that the reality of such changes has been contended for by many eminent selenographers from Schroeter onward.

It has been argued, chiefly by those astronomers who never study the moon, that slight differences in illumination, libration, seeing, etc., cause considerable differences in the appearance of lunar marks so that no two observations can ever be made under the identical conditions essential to deciding whether irregular changes exist or not;[71] however, this point of view ignores several facts:

1. *Lunar observers* learn by *experience* what differing appearances, changing seeing, transparency, etc., give rise to; hence, if they have recorded all the data we recommended early in this paper, they can usually decide whether or not a difference in two observations can be plausibly attributed to a real variation.

2. Under high illumination a change of *several dozen degrees* in the sun's position in the lunar sky seldom causes much change in appearance; therefore, under such lighting the far smaller variations in libration and the sun's latitude can be largely neglected.

3. Libration is unimportant near the centre of the moon.

In 1939 I initiated a programme of regular observations of about 25 marks suspected of changing irregularly and hope in the near future to finish this project and report the results.

Concerning the Earth-lit Moon

Changes due to incident light do not depend upon the source of illumination; areas so altering would accordingly appear the same upon the earth-lit moon as upon the full moon, except as changing libration and variations in the selenographic latitudes of the two illuminating bodies would cause some differences. Therefore, it is highly desirable to examine by earth-shine areas suspected of being vegetation, clouds, frost, etc.

The faintness of the earth-shine and light diffused from the brilliant sunlit crescent, a circumstance suggesting the use of some of the techniques employed by Lyot in photographing the corona without an eclipse,[74] make such observations difficult. Probably a very clear sky and an aperture of at least 15 inches are essential to good results, for study of the earth-lit hemisphere in Ohio and Iowa with apertures of from 6 to 12 inches has not enabled me to decide whether or not changing areas then possess their full-moon aspects. To be sure, a number of high-sun dark areas, including those near Mount Bradley, in Riccioli, and near Firminicus, have been seen; moreover, no appearances not present on the full moon have been recorded. Shaler long ago found the same prominent marks on the earth-lit moon as on the full moon.[71] Pickering once remarked:[68] "That the fields [high-sun dark areas] are nevertheless somewhat darker and smoother than their surroundings is shown by the fact that when a photograph is taken of them by earth-light they are seen as comparatively dark areas."

The earth-shine is perhaps best studied photographically; certainly the obtaining of a *good set* of photographs of the earth-lit moon and of a sequence of comparison-photographs of the full moon is a project very much worth while. Apparently earth-shine photographs are very rare. Barcroft and I could locate during a brief search only one, which was taken by Barnard at the Yerkes Observatory on February 14, 1907; it shows much detail but not nearly enough for the purposes of the investigation under discussion.

The Temperature of the Moon's Surface

In measuring the temperature of the moon's surface, it is necessary to distinguish between solar heat which is simply reflected and that which is first absorbed by the moon and later re-radiated. The theory of such measures has already been well explained.[44, 71, 74] Probably the most accurate work is that which has been carried on by Pettit and Nicholson at Mount Wilson, and Table X is based upon their published results;[44] but the values in it are to be regarded as averages, for the rough lunar surface appears to radiate more heat toward the zenith than toward the horizon.[44]

Table X.—Temperature of the Moon

Sun's height	Temperature	Sun's height	Temperature
90°	214° F.	20°	32° F.
70	194	10	−58
50	140	<0*	−243
35	86		

*Sun below horizon.

As regards the temperature of the moon's surface during a lunar eclipse, the most reliable measures are those Pettit made in 1939. He found that near the centre of the disc the temperature fell from about 210° F. to about −100° F. during the partial phase, and throughout totality continued to drop, though more and more slowly, finally reaching −143° F.; it then rapidly regained its original value after the umbral shadow had passed.[44a]

The preceding figures are of interest, but it would be more instructive to know the lunar daily temperature-changes and the eclipse-induced variations of small areas of various kinds (e.g., the central mountain of Aristarchus and the dark area in Riccioli); and such small areas can surely be measured as easily, if not more easily, than various portions of the small disc of Mars.[6] We should expect on the moon little decrease in temperature with increasing altitude (e.g., on tops of mountains) because of the homogeneity of the lunar atmosphere.[47]

The observed temperatures are to be borne in mind when we attempt to interpret lunar changes. Referring to Table X, we conclude that snow cannot exist, unless in shadowed crevices, except during the first and the last day or two a region is in sunlight

and that any gradual melting or depositing of frost or snow over a period of several days is improbable. Any lunar vegetation must be capable of withstanding great extremes of heat and cold; and it would be well to test whether any very hardy terrestrial plants can flourish near the temperature of boiling water and can survive exposure to the temperature of liquid air, an experiment suggested by Pickering in his last lunar paper.[70]

Concluding Remarks

It is surely by now obvious that the prevailing opinion that nothing ever happens on the moon rests on inadequate evidence and that in reality the moon offers many interesting problems for investigation. No single observer can hope to study comprehensively all aspects of lunar work, and it is certainly highly desirable that amateur astronomers possessing telescopes not exclusively engaged in other researches should devote some time to the moon. Most of the observations discussed in this paper were obtained by "ordinary" apertures of from 6 to 10 inches (Table III). I urge all amateur astronomers (and professionals also) interested in lunar matters to communicate with me. Blanks for recording notes and drawings and instructions for so doing will be furnished free of charge. The co-operative efforts of an association of lunar observers can greatly further our knowledge of the moon.

A word of warning and advice, long ago uttered by Douglass[9] and strikingly supported by the experience of several of my colleagues and of me, should be added. At first view almost all lunar detail will seem difficult; any first-class work, impossible. Only those observers who "persistently and persistently keep at it, picking up bits of detail, little by little, even though the seeing seems bad and the object difficult; always and only with the stern determination to see something if that something exists"[9] will ever obtain valuable and pleasing results. The beginner should *expect* several months to pass before his drawings show much detail.

It is a pleasure to acknowledge that the preparation and publication of this paper have been greatly facilitated in numerous ways by the generous assistance of Mr. Barcroft. Dr. Lincoln La Paz,

of the Ohio State University, and Mr. Frank R. Vaughn have also aided. I further wish to thank the *Journal of the Royal Astronomical Society of Canada* for publishing the paper, the co-operating observers, and many others, too numerous to be mentioned individually, who have contributed in various ways to the development of the ideas presented.

New Waterford, Ohio,

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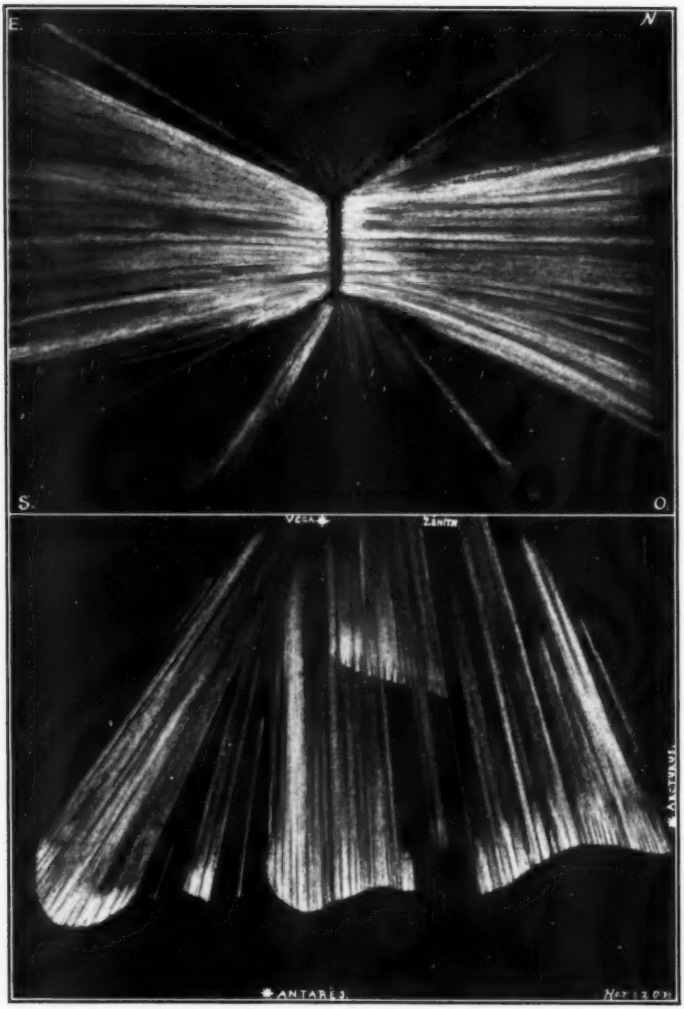
PLATE XVII



L'Aurore boréale du 18 Septembre 1941 observée à Montréal
par J. Edgar Guimont.

No. 1, *bas*, Eventail ou Rideau.
No. 2, *haut*, Aspect au zénith.

Journal of the Royal Astronomical Society of Canada, 1942. Dessins par J.E.G.

AURORE BOREALE VENANT DU SUD

Observée à Montréal, le 18 Septembre 1941

Par Jos. Edgar Guimont

(With Plate XVII)

JEUDI soir, le 18 septembre 1941, à 7h. 15m. (heure solaire), comme je sortais à l'arrière de ma demeure, je vis monter de l'horizon sud-ouest, des lueurs étranges. . . .

Serais-ce une aurore boréale me dis-je? Contrairement à ce que j'ai déjà observé, ces lueurs, au lieu de venir du nord pour se diriger vers le sud, venaient plutôt de cette dernière direction, montaient au zénith, puis se dirigeaient vers le nord.

A peine étais-je revenu de ma surprise, qu'instantanément et à mon grand émerveillement, je vis un rapide déploiement lumineux. Je reintégrai ma demeure, j'avisai mon épouse et tous deux nous nous élançâmes dans la rue, pour voir au-dessus de notre tête, la manifestation aurorale la plus étrange jamais vue.

Un Anglais passant près de nous, demanda: "What's that?" Sous l'emprise de l'enthousiasme, je lui criai: "A wonderful aurora comes from the south!"

Ce fut un orage magnétique merveilleux. Jets, filaments, draperies, lueurs fulgurantes, tout se conjugait en une exubérance fantastique!

Les lueurs coloriées fulminaient avec une intensité et une rapidité telle, que l'ensemble du phénomène devenait une prodigieuse et extraordinaire féerie!

Des vagues de lumière prenaient naissance au zénith, près de Véga de la Lyre, pour rapidement se diriger vers le sud et s'évanouir au-dessus d'Antarès du Scorpion.

A une vitesse fulgurante, le phénomène se manifesta dans un cadre s'étendant du carré de Pégase (au sud-est) à Arcturus du Bouvier (au nord-est) et d'Antarès à Véga.

Mon croquis en forme d'éventail (Dessin No. 1) et celui (Dessin No. 2) représentant une couronne avec noeud central se manifestant au zénith, ont été dessinés durant la période intensive de 7h. 20m. à 7h. 35m. (heure solaire).

A 8h., j'aperçu une autre fluorescence prodigieuse, évoluant au zénith.

A 8h. 20m., l'aurore se dirigea vers le nord et forma un arc.

Au nord, la manifestation s'étendit de Mars à Arcturus, toutefois, l'intensité se manifesta surtout de Cassiopée à la Grande Ourse.

A 8h. 25m., je pris un croquis de l'aspect lumineux de l'arc, qui serpentait dans le ciel comme dans une mer électrisée. (Ce troisième dessin, demeure avec mon dossier original et ne vous a pas été expédié.) Simultanément, forme et intensité varièrent constamment.

A 8h. 30m., les projections fluidiques et les rayons lumineux se métamorphosèrent en nuages floconneux dans toute l'étendue de la coupole céleste, puis, la manifestation grandiose diminua et s'étendit en lueurs jaunâtres comme un immense feu de Bengale.

A 8h. 45m., il ne demeura plus à l'horizon nord, que de faibles lueurs diffuses.

Durant toute la soirée le temps fut calme et frais, le ciel clair et sans lune.

THE ASTEROIDS*

By E. S. KEEPING

BACK in the year 1772 a German astronomer named Bode stated a curious law that he had found concerning the distances of the various planets from the sun. If we write down the numbers

0 3 6 12 24 48 96 192 384 768

each, except the first, being half the one following, and add 4 to each, we get

4 7 10 16 28 52 100 196 388 772

and these numbers, according to Bode, represent the relative distances of the planets from the sun. If the actual measured mean distances of the planets known in Bode's day are set out on this scale, taking the Earth as 10, we get

Mercury	Venus	Earth	Mars	—	Jupiter	Saturn
3.9	7.2	10	15.2	—	52	95

and, except for a gap between Mars and Jupiter, the agreement is remarkably close. Then in 1781 Sir William Herschel discovered a new planet. This was a most important and exciting event, since all the other planets had been known since remote antiquity. The planet was at first named Georgium Sidus in honour of George III, but Bode suggested the name Uranus which has stuck. As he did not fail to observe, the distance of Uranus (192) fitted in very nicely with his law.

Much later a still more distant planet was suspected, because of unexplained irregularities in the motion of Uranus. In 1846 it was discovered and named Neptune. In attempting to find its orbit, Adams and Leverrier provisionally assigned to it the mean distance which would be given by Bode's law, but, as it turned out when more accurate observations were available, this was a very poor approximation. Instead of 388 as given by the law, measurement showed only 301.

Still more recently, another planet Pluto has been added to the sun's retinue. But Pluto is far nearer than Bode's law would suggest,

*An address delivered to the Edmonton Centre of the R.A.S.C.

395 instead of 772. In fact it is not very far from the predicted position of Neptune. The so-called law therefore breaks down completely. It is not a natural law like Newton's law of gravitation but a curious coincidence. It has no theoretical foundation, and its principal use is to provide an easy way of remembering the approximate relative distances of the nearer planets.

Bode's law, however, was the direct cause of the discovery of the asteroids. On account of the gap in the series between Mars and Jupiter, an extensive search was carried out in the latter part of the 18th century for the missing planet, and on January 1st, 1801, the first day of the nineteenth century, the Italian astronomer Piazzi discovered a tiny planet which was named Ceres. Shortly afterwards it was lost again in the glare of the sun, but was rediscovered a year later. The rediscovery was due to the great German mathematician Gauss, who had worked out a new method of computing orbits from a very small number of observations. From the few measurements that Piazzi had been able to make, Gauss computed an orbit, proved that the new object was a minor planet between Mars and Jupiter, and predicted its position a year later within half a degree of where it was actually found.

Three other minor planets, Pallas, Juno and Vesta, were found by 1807. The fifth, Astraea, was not discovered until 1845, but since then a diligent search has been rewarded by the addition of several thousands of little planets, or asteroids as they are called, to the sun's family. About 1500 of these are definitely known and have had their orbits computed. It is curious that the mean distance of the asteroids from the sun is very close to that of the missing planet predicted by Bode's law, although the range in size of the orbits is quite considerable. A few asteroids are nearer the sun than Mars, a few others are farther out than Jupiter, but on the whole they average about 2.7 times the radius of the earth's orbit, whereas Bode's law would give 2.8. This coincidence inevitably suggested that the asteroids might be the shattered remains of a planet that once existed but has since blown up. Whether this is so, it is impossible to say. If all the asteroids had a common source we should expect certain similarities in the orbits, although the perturbing action of Jupiter could easily have changed most of the orbits by now beyond recognition. As a

matter of fact, some astronomers have recognized five distinct groups of asteroids with orbits so closely related that they could have easily arisen from the explosion of a larger mass, but why there should have been five separate explosions, or when they happened, are completely unknown. It has also been suggested that the asteroids originally formed part of a ring like Saturn's, and that the disturbing effect of Jupiter caused this ring to break up into fragments which partly coalesced to form the asteroids, but all this is pure conjecture.

Asteroids are discovered nowadays by photography. A region of the sky near the ecliptic is photographed with an exposure of two or three hours. The telescope is moved continuously during the exposure to follow the apparent motion of the stars so that they appear on the photograph as dots. But if there is an asteroid in the field of view its motion relative to the fixed stars during the time of exposure will cause it to appear as a distinctly elongated trail, and so it is easily picked out. On one photograph made at Heidelberg there were no less than three asteroid trails. These trails point in different directions and are of very different brightness. On the average, asteroids move eastward among the stars about a quarter of a degree a day, but the nearer the asteroid, the longer and usually fainter the trail it will make.

The man who discovered the fifth asteroid, Astraea, spent fifteen years hunting for it, but with the advent of the photographic method the pace of discovery increased enormously. The following table taken from Watson's recent and valuable book "Between the Planets", gives the number of asteroids found in each decade from 1800 onwards, and also the number for which orbits have been computed. It will be seen that most of the later discoveries have either been lost again or have turned out to be already known.

Decade	Number discovered	Number of orbits computed
1800-09	4	4
10-19	0	0
20-29	0	0
30-39	0	0
40-49	6	6
50-59	47	47
60-69	53	52

Decade	Number discovered	Number of orbits computed
1870-79	105	102
80-89	80	76
90-99	264	165
1900-09	776	213
10-19	788	249
20-29	1262	202
30-39	2799	373

At first the asteroids were named for Greek and Latin goddesses, Ceres, Pallas, Vesta, etc., but after a time the supply of names from classical mythology was exhausted. Then names of cities or countries were given, like Chicago, Bavaria and Pittsburghia, or the names of the wives or daughters of well-known astronomers. One is named Hooveria in honour of the work of Herbert Hoover on European relief after the last war. Nowadays asteroids usually get just a number, and not even that until they have been observed several times at intervals of some weeks so that an orbit can be computed. If they turn out to be specially interesting, however, they are usually given a distinctive name. The official register of asteroids is kept in Germany where a great deal of the work has been done. Reinmuth at Heidelberg himself made 980 discoveries, of which 189 have been duly entered in the register, and another man, Wolf, also at Heidelberg, has contributed no less than 228 entries to the official register.

Only one of the asteroids, Vesta, is ever bright enough to be seen with the naked eye, and then only under the most favourable circumstances. The sizes of the "big four" were measured by Barnard, who gave the diameters as Ceres 480, Pallas 306, Vesta 241, and Juno 121 miles.

All the others are much smaller, some 40 or 50 miles across, some only a mile or two, like a good-sized mountain careering through space by itself. They are all, of course, much too small to keep any atmosphere. The sizes of the fainter and smaller asteroids cannot be measured directly but are estimated from their brightnesses. We know from the measurements on the big four that their reflecting power is about equal to that of Mercury or the moon, except that Vesta, which is only half the diameter of Ceres, is actually slightly brighter, so that for some reason its reflecting power must be about

four times that of Ceres. For the smaller asteroids we assume an average reflecting power, and calculate their diameters from their absolute magnitudes, i.e. the magnitudes they would have if they were all at the same distance from us as the sun. A magnitude of 10 corresponds to a diameter of 17 miles. As most of the known asteroids have absolute magnitudes around 8, 9 or 10, they are obviously very small, as planets go, although quite sizable lumps of naked rock.

The light that comes to us from the asteroids varies from time to time. They have phases like the moon, but the changes are not so great, since we nearly always see them near full phase. The reflecting power of a rocky surface depends a good deal on the nature and colour of the surface, and careful observation of the colour of the light from the brighter asteroids suggests that most of them have a greenish or brownish surface. Very few appear to be bluish. The light of Vesta has been analysed by means of polaroid sheets or crystals of Iceland spar, and it was found that she reflects about the same percentage of polarized light as the moon or Mercury. From measurements of moonlight it seems probable that the actual reflecting surface of the moon is a layer of soft porous material like volcanic ash. Since one would hardly expect volcanoes on Vesta, the layer of dust is most likely the result of continued bombardment by meteors and meteorites.

It is unlikely that any of the brighter asteroids remain to be discovered, but it is estimated that there may be 50,000 or even 80,000 down to the nineteenth magnitude, and the majority of these still await discovery. The computation of orbits for all these will be an enormous task, especially as the gravitational attraction of Jupiter tends to throw the orbits out, so that they require continual correction and recalculation. Fortunately there has been a great development in electrical computing machines specially devised for such work, and the labour may now be materially reduced. Most of these asteroids are so small, however, that the total mass of the whole lot is probably less than that of the moon.

The asteroids, like all the planets, move in ellipses, but usually in much more elongated ellipses than the planets, whose paths are not far off circular. The most eccentric orbit so far found is that of

number 944 (Hidalgo) which at one point is not far outside Mars and at another point of its path is almost as far out as Saturn.

The periods of the asteroids range from about 3½ years to 6 years. Not a single one has been found to have a retrograde motion like some of the moons of Jupiter. The inclinations to the plane of the Earth's orbit vary around an average of about 10°. Most of them remain pretty well in the band of the Zodiac.

The massive planet Jupiter has a great effect on the paths of asteroids, particularly if their periods happen to be equal to his own period or to some simple fraction like 1/2, 1/3, or 2/5 of it. It is well known that if you apply a small force regularly at the right times to a swing you can easily set it swinging through a large angle, and something of the same sort of effect is produced by the pull of Jupiter occurring time after time at the same part of the asteroid's path. The asteroid is eventually pulled right out of its natural path into a peculiar orbit, and the result is that very few asteroids remain with periods which are simple fractions of the period of Jupiter. If a distribution is drawn up of the numbers of all known asteroids with different periods, there are noticeable gaps at these places.

The group of asteroids which have approximately the same period as Jupiter form a special class known as Trojans, of which 12 are known. They occupy positions of equilibrium at Jupiter's distance from the sun, but 60° ahead of or behind the planet. The Trojans, Jupiter and the sun are thus at the three corners of an equilateral triangle, and this position is relatively stable. However, Saturn occasionally upsets the arrangements and makes one Trojan wander off too near Jupiter, when its orbit gets so radically altered that it drops out of the Trojan group. Also, of course, the converse process may happen, and an asteroid may be captured by Jupiter and become a Trojan, so that membership of the group, although it may last for a very long time, is not really permanent. We can be sure that the present arrangement of asteroid orbits is very different from what it was when the solar system was founded. Uncertainties in the perturbations, moreover, prevent any accurate calculation of what the orbits formerly were, at any rate for more than a few million years back.

There is one asteroid which must be singled out for special men-

tion. Number 433, since called Eros, was discovered in 1898, and has since been the subject of most careful and concentrated attention by observatories in all parts of the world. It is a small body, probably less than 15 miles across, but it happens to pass at times fairly close to the earth, and observations of its path have given us the best value we have of the most important distance in the whole of astronomy, the distance of the earth from the sun. This is so important because it is the yardstick of the Universe, and all our estimates of distances to planets, stars and nebulae ultimately depend on it. If a surveyor has to measure a distance which cannot be found directly with a tape, he measures some convenient known base line and a couple of angles and calculates the unknown distance by trigonometry. Thus if AB and the angles CAB and CBA are known, the distance BC is easily calculated. If C represents the sun, and A and B are two places on the Earth's surface a known distance apart, BC can be found from the difference between the directions of the sun as seen from these two places at the same instant. This difference, which is equal to the angle ACB, is however very small. Its greatest possible value is only about 17 seconds of arc, which is the angle subtended by a 25-cent piece at a distance of 300 yards. Moreover the sun is a difficult body to observe accurately, because of its size and the effect of its heat on the instruments used, so that if we depended on direct observation of the sun we could not hope to avoid very large errors in the measured distance. However it is easy to get *relative* distances of the various planets within the solar system—these are found from Kepler's third law when we know their periods of revolution—so that if we know one distance accurately we can find them all. Measurements of the planets that pass nearest to us therefore give the best chance of getting a distance accurately, and in fact observations on Mars gave the first reasonably good value of the distance to the sun. A favourable opportunity is when the earth and Mars happen to arrive simultaneously near the points where their orbits approach most closely, about 34½ million miles apart. In 1672 such an opportunity occurred and was observed by Cassini from Paris,

while a special expedition went to Cayenne in South America to observe at the same time. The result was to place the sun at between 82 and 91 million miles, with a probable value of about 86 million miles. Other methods were later used, based on the occasional transits of Venus across the sun's disk, on the motions of the moon, the aberrations of stars, and so on, but even as late as 1882 the estimated uncertainty in the distance to the sun was at least 1½ million miles. It was suggested as long ago as 1872 that some of the asteroids might prove useful in determining the scale of the solar system, and the method was successfully used on three asteroids in 1888 and 1889, but it was the discovery of Eros that really gave astronomers their opportunity. In 1901 it passed the earth at less than 30 million miles, but in 1931 it was only 16 million miles away, and the occasion was eagerly seized upon to determine as accurately as possible the size of the solar system. The method was to photograph Eros and surrounding stars on a large number of plates and then by careful measurements to determine its exact path among the stars. Comparison of photographs taken at different observatories should show slight variations due to the distance apart of the stations, and since these distances are accurately known the distance of Eros can be found.

Several thousand comparison stars were used and the exact positions of these had to be determined, a laborious piece of work in which thirteen observatories collaborated to form a general catalogue of star positions. In the observations of Eros itself, twenty-five observatories collaborated, situated in England, Belgium, Germany, Italy, Spain, Czechoslovakia, Russia, India, Japan, China, Algeria, South Africa, Argentina and Australia. The British Astronomer Royal, Dr. H. Spencer Jones, was in charge of the whole programme and issued careful instructions to all the observatories as to methods of work and details of technique so as to ensure as uniform a standard of accuracy as possible. He himself calculated and reduced the very extensive data accumulated. The photographs were taken in 1931 and the subsequent measurements and calculations consumed ten years. In 1941 the Astronomer Royal was able at last to present to the Royal Astronomical Society of England the results of this laborious but important piece of work. The material proved to be

very satisfactorily consistent when analysed in several different ways, and the net result was to fix the distance of the sun as 93,005,000 miles, with an uncertainty either way of about 9,000 miles, so that the round figure of 93 million miles is as accurate a value as can possibly be given. If anyone thinks that an error of 9,000 miles is fairly considerable, he should reflect that the calculation rests on the measurement of a very small angle and that the uncertainty corresponds to an error in this angle equal to the angle subtended by the thickness of a human hair at a distance of ten miles, i.e. one thousandth of a second of arc. To have achieved an accuracy like this is indeed something to be proud of, and is a splendid example of that international co-operation in science which we may hope to see re-established when the dictators have been finally defeated.

Eros is of interest in another way, because of its very peculiar variations of brightness. Sometimes it drops 1.5 magnitudes, rises again, drops, and rises, all in about 5 hours, then for years it shows little variation, and then the extreme variations appear once more. The analysis of a long series of observations suggests that Eros is not spherical but shaped like a rather irregular brick, rotating about an axis nearly perpendicular to its greatest dimension. When this axis is more or less in our line of sight there is little apparent variation in brightness, but when we are viewing Eros along a line in its equatorial plane we see sometimes an end and sometimes a side, and there are great differences in the brightness. This happened for instance in February 1938. When Eros was nearest to us in 1931 its size was computed to be about 22 kilometres or say 14 miles long, by 4 miles across. Its surface is probably very rough and irregular. It is a huge spinning splinter of rock.

Other asteroids show similar variations, though usually on a smaller scale. The brightest of all, Vesta, is one of the most erratic, and no complete explanation is yet forthcoming.

There are some asteroids that come even nearer to the earth than Eros. Appollo, discovered in 1932, came within less than 2 million miles, Adonis in 1936 passed at less than a million miles, while Hermes, discovered in 1937, came as close as 700,000 miles, or less than three times the distance of the moon. The orbits of all

these are highly eccentric and are inclined at only a few degrees to the earth's orbit.

On the discovery photograph of Hermes the asteroid looks like a meteor, so fast was it travelling. On October 30th, 1937, when it shot past the earth, it was moving five degrees an hour, and although of the eighth magnitude was missed completely by many astronomers who tried to photograph it. In fact, the only photographs available for finding its orbit were ones taken for other purposes, on which it happened to appear. In consequence its orbit is very uncertain, and it is unlikely that it will be picked up again except by chance.

There may be hundreds more of these tiny planets, a few miles across, not yet discovered. When we find them getting almost as near as the moon we may be excused for being a little apprehensive about the chances of actual collision with the earth. However, it seems likely that such a collision would not occur more than once in a hundred thousand years, although if it *did* happen it would do a tremendous amount of damage in the place where it hit. But even sizable meteorites are quite rare visitors to the earth, so that the chances of being hit by an asteroid are not worth losing sleep over. Still, these tiny unregarded members of the sun's family may be as interesting and important in their way as their far more massive and resplendent brothers and sisters that we see with our own eyes parading majestically among the stars.

University of Alberta,
Edmonton, Alberta.

THIRTY-FIRST ANNUAL MEETING OF THE A.A.V.S.O.

By D. W. Rosebrugh

THE thirty-first Annual Meeting of the A.A.V.S.O. was held at Harvard Observatory, Cambridge, Massachusetts, on October 9 and 10, 1942, through invitation of Dr. Harlow Shapley. While the attendance was less than in previous years yet there were some fifty present.

Mr. Leon Campbell presented his 11th Annual Report as Recorder, showing that 33,090 observations had been made during the year, 940 of them by five active Canadian members.

During the year Mr. Campbell has discussed 450,000 observations of 250 long-period variable stars, made during the last 20 years. About 25 possible correlations were studied and some were found to exist. Among these are: Stars with longer periods have later spectral types M5, 6, 7 or 8, as compared to the earlier spectral types M1 to M5 for shorter period stars; stars with smaller ranges, e.g., 2 magnitudes, have shorter periods than those with larger ranges such as 8 magnitudes; stars which rise faster from minimum have longer periods; stars with steeper rate of rise have later spectra; stars with longer periods tend to congregate closer to the galactic centre than those with shorter periods.

If one can speak of an "average" or "typical" star, this typical star of the 250 long-period variable stars under review has a maximum of 8.9 magnitude, a minimum of 13.5 magnitude, a period of 312 days, the time taken to rise to maximum is shorter than the time taken to fall to minimum in the ratio 0.86 to 1.00, and the time spent at minimum is longer than that at maximum in the ratio of 1.0 to 0.9.

Mr. Campbell commented in general on these 250 stars in the following terms: Points of inflexion seldom occur on the decreasing slope of a long-period variable, whereas such points usually occur on the decreasing slopes of cepheids; each long-period variable star tends to run true to its own particular form; and no one long-period variable star has been found which presents all the many types of deviation from normal.

Mr. Bertram J. Topham of Toronto was elected a Councillor.

Mr. Roy A. Seely of New York, formerly of Montreal, was re-elected First Vice-President and Mr. David W. Rosebrugh of Lakeville, Connecticut, formerly of Toronto, was re-elected Secretary. Dr. Dirk Brouwer, Director of Yale Observatory, was re-elected President; Mr. Leon Campbell, Pickering Memorial Astronomer, Harvard, was re-elected Recorder; and Mr. Percy Witherell of Boston was re-elected Treasurer.

Four members are in the American armed forces and two others are prisoners of war.

The Auroral Committee of which Mr. Topham is a member reported that co-operative observing, aided by short-wave radio between the Milwaukee group and Cornell and Colgate Universities has had to be discontinued for the duration, but individual reports of aurorae seen are still welcomed by Cornell.

Dr. Sergei Gaposchkin of Harvard told about the eclipsing variable star S Doradus. Minima occurred in 1891, 1900, 1930 and 1941, corresponding to a period of about 40 years, with an eccentricity of 0.4. The two components are of approximately equal size and are about as large as Saturn's orbit. Their centres are separated by twice the radius of Pluto's orbit. S Doradus is intrinsically one of the brightest stars known. It is also the hottest except for the nuclei of planetary nebulae.

Dr. Cecilia Payne-Gaposchkin of Harvard described the RV Tauri type of variable stars. Only 29 of these odd stars are known, but R Scuti, which can be followed with binoculars, is well known to A.A.V.S.O. members. RV Tauri stars are characterized by alternate deep and shallow minima, which sometimes interchange places,—thus two shallow or two deep minima may occur together. In the case of R Scuti this interchange takes place about every 7th cycle. In line with the theories of Dr. Martin Schwarzschild it is considered that the RV Tauri stars may be oscillating with a fundamental frequency and also a second harmonic frequency and the intermingling of these different frequencies produces a very erratic light-curve. RV Tauri stars are yellow, of spectral types F, G and K. They are supergiants of absolute magnitude −3. R Scuti is considered to be a G2 or G0 star, but its spectrum is of K type at minimum, corresponding roughly to 3700 degrees. Its light is bluer at the cooler minimum than at the hotter maximum

because at minimum its spectrum shows absorption bands of titanium oxide in the red, so that the red portions of its light are absorbed at minimum and hence the remaining star light is bluer than at maximum.

DF Cygni which has been studied intensively by Miss Margaret Harwood of Nantucket is the best known RV Tauri star. The heights of maxima of this star vary from time to time by as much as 3 magnitudes. UU Herculis presents the most anomalies, as it seems to have a 90-day period of the RV Tauri type and a 70-day period resembling a cepheid in shape (though much longer than any cepheid) and it "clicks" back and forward between these two types of variation.

Dr. Zdenek Kopal of Harvard made a plea for frequent observations of the times of minima of Algol by amateurs. These occur during darkness about four times a month, but during some years not a single observed minimum of Algol is reported. Despite the fact that Algol is an eclipsing variable and hence should be expected to be as regular as clockwork, a long-period change which has now accumulated to 3 hours in the times of minima, during the last 160 years, has occurred. The star is now known to have a third component, probably a white dwarf, whose influence on the period can be allowed for, but it may be necessary to postulate yet a fourth companion whose dynamical perturbations may have caused the shift in the time of minimum in question. Available data seem to indicate that this fourth companion should be 5 seconds of arc from Algol and hence clearly detectable in large instruments unless a red dwarf, but such a companion has never yet been reported and the available data are too fragmentary to make its existence a certainty.

Mr. D. W. Rosebrugh demonstrated a Richest Field Reflecting Telescope of 4¼-inch aperture and 15-inch focal length which he had assembled on a portable alt-azimuth mounting at a total cost of $33. With a refractor finder of 1¼-inch aperture and power of 6 and with two Ramsden eyepieces giving powers of 15 and 40 this RFT makes a most serviceable instrument with which he had already made over 100 variable star observations during the two months since it was completed. DQ(Nova) Herculis 1934, now at 11.7 magnitude on its decline, is clearly visible with the 40-power eyepiece, while the 15-power eyepiece is admirable on bright vari-

able stars from the 6th to 9th magnitudes. Such a telescope however is of little use on the planets, though the star cluster in Hercules, the nebula in Andromeda and the Milky Way show to good advantage in it.

Mr. J. J. Neale of New Haven, Connecticut, reported that he had found it possible to make valuable occultation observations of Aldebaran in daylight with an 8½-inch refractor at Yale. Perhaps occultations of fainter stars by the moon can also be observed in daylight.

Dr. and Mrs. Shapley entertained the A.A.V.S.O. members at lunch on Saturday, October 10, and as always this was one of the most enjoyable features of the program.

Lakeville, Connecticut,
October 17, 1942.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Edmund Halley and Isaac Newton

Born on October 29, 1656, the son of a well-to-do soap maker, Halley gave early promise of unusual intellectual powers and at the age of 16 had determined to find a career in astronomy. His first serious paper was laid before the Royal Society ere he had reached the age of 20, he was a member of the Society at the age of 22, and continued his very active career almost to the year of his death at the age of 86.

Let us turn to the year 1684, and imagine ourselves strolling along the streets of London—less crowded then than now—on a summer afternoon. Near the entry to the rooms of the Royal Society we come upon three gentlemen engaged in earnest conversation. The youngest of these, only 28, but already enjoying a European reputation, we recognize as Edmund Halley. He was saying that he had been giving a great deal of thought to Kepler's Third Law and the nature of the force it expressed, and had come to the conclusion that it must be a force varying inversely as the square of the distance of the body—planet or comet (he was specially interested in comets at the time)—from the sun and that the body must describe the curve of an ellipse, but he had been unable to prove it. It may be well to recall that the only comets then known were the brilliant, naked-eye ones which come into view from time to time from almost any direction in space.

The second man in the group, Sir Christopher Wren, who was almost as well known as a mathematician and astronomer as he was for the buildings he designed, had given the matter no thought; the third, Robert Hooke, the well-known physician and physicist, however, promptly said Halley was right. He had himself proved it conclusively some years before, but when challenged he could not produce the proof, nor could he outline his argument. It came out, in the course of the conversation, that Hooke knew that Isaac Newton, at Cambridge, had been at work on the theory of planetary motions a dozen or more years earlier, but had published practically nothing on the subject.

Whether or not the particular conversation I have just imagined

took place, I do not know; but it is a matter of record that these three friends were in the habit of discussing their scientific problems with each other, that they discussed this particular problem in 1684 and that Halley, who had never met Newton, wrote to him in August 1684, asking for the privilege of calling on him.

Newton at once replied, granting the request and received the younger man most cordially. Halley put his question, and gave his views, and Newton agreed that he was correct and added that he had himself worked out the proof at least fifteen years earlier, but, becoming dissatisfied with the work, had put it aside and had never arranged it for publication. He outlined his argument and Halley was not only convinced but delighted and urged upon Newton the desirability of at least presenting his papers to the Royal Society to assure his right to priority in the great discovery even if he were not ready as yet to publish.

Why Newton delayed the completion of the *Principia* so long is a subject with which we are not here concerned. It is still unsettled. Here it is enough to state that Newton finally yielded to Halley's persuasive arguments, put his papers into the form in which they appear in Book I of the first edition of the *Principia*, and sent them to the Council of the Royal Society early in 1685. When the Council received them they turned them over to Halley with instructions to report, and on his enthusiastic report it was voted that they be printed at the expense of the Society. A little later, they found it necessary to recall this vote, and, at Halley's generous offer, order them printed at the "personal expense of Mr. Edmund Halley." These papers practically constituted what became Book I of the first edition of the *Principia*. Newton a little later added Book II and later still Book III. He had planned to suppress this third book because he felt it to be incomplete, but Halley persuaded him to retain it.

Halley threw himself into the work of editing and printing what he in one place called "your divine treatise" with great enthusiasm. In March 1687, after receiving the manuscript of Book III, he told Newton that he was "resolved to engage upon no other business till such time as all is done; desiring to clear myself from all imputations of negligence in a business in which I am much rejoyced to be any-

wais concerned in handing to the world that that all future ages will admire."—An extract from Leaflet No. 164, of the Astronomical Society of the Pacific, by Robert G. Aitken.

The Equation of Time

In mathematical philosophy Time is one of the fundamental concepts and a rational treatment of it leads to many difficulties. To the practical astronomer, especially the amateur, the various kinds of time are extremely confusing. In the *Observer's Handbook* on page 8 there is a brief summary of apparent, mean, sidereal, standard and daylight saving time; but difficulties met in observserving are continually reported. One of these is the meaning of Equation of Time. The definition of this quantity has varied in the past fifty years, and indeed sometimes it is used in two slightly different ways in the same volume. For instance in the *American Ephemeris* for 1943 on pp. 2-16, when dealing with 0^h G.C.T., otherwise known as U.T., the Equation of Time is defined to be Apparent Time *minus* Mean Time; while on pp. 562-569, where the tables are for Washington Apparent Noon, the Equation of Time is defined to be Mean Time *minus* Apparent Time. One must carefully look for the definition of the term when using tables in which it appears.

In the *Nautical Almanac* (British) for 1938 on p. 803 is a very lucid statement, which may clarify the ideas in the minds of some of our readers:

> The difference between mean time and apparent time is known as the *equation of time*. This quantity is also the difference between the hour angles of the mean and true sun, or between their right ascensions. When this term was first introduced it was the practice to determine apparent time from a sun-dial, or from observations of the sun, so that the equation of time was then considered to be mean *minus* apparent time, or the correction to be applied to apparent time to reduce it to mean time. To-day mean time is ascertained by the astronomer by conversion of the sidereal time obtained from stellar observations, and by the navigator from wireless signals, so that the *Nautical Almanac* now tabulates the correction to be applied to mean time to give apparent time.

Indian Summer

Many years ago a well-known meteorologist told the present writer that there was no definite period of the year which was

acknowledged as Indian Summer. That may be so, but we shall all agree that the name is at least a very pleasing fiction. This year, after an enjoyable summer and a perfect autumn, together with a bountiful harvest in Central Ontario and, the writer believes, generally throughout Canada, the mild sunny weather is extended into November. It is cheering in these fateful days. Frank Thone, of *Science Service*, gives some useful information on the subject, as follows:

The first sharp frosts came early this year over a wide stretch of this country; Indian summer is here correspondingly soon. The quiet, warm autumn days, with calm air or, at most, moderate, drying winds, are good for hastening the maturing of the crops. They dry the last surplus water out of corn, beans and other seed crops, mellow late apples and pears, and put the finishing touches on pumpkins and hard-shelled squashes left orphans by their frost-killed vines.

There is no fixed date for the arrival of Indian summer, no definite duration for the season. It is not even necessary that a killing frost come first, though that is a usual preliminary. Any warm, quiet spell, following cool or chill fall weather, may be called Indian summer. In some fortunate falls there may be more than one such season.

Meteorological background for Indian summer is a "stalled" high-pressure area somewhere in the south-east with a large area of low pressure backed up in or near the Yukon valley. There will then be little air movement off the main body of the continent, and even the low-angled autumn sun can warm up the air. Sometimes Indian summer temperatures rival those of actual summer: 90-degree days are not uncommon, though nights are always cool.

Only in the English-speaking parts of North America is the name Indian summer used. Similar seasons in Europe have names dating back to the Middle Ages, ascribing them to various autumnal saints; usually St. Martin, whose feast comes on November 11. The ancient Greeks had a belief that these calm spells were a gift of the gods for the special benefit of the kingfisher, whose name in Greek is halcyon. The kingfisher was supposed to build a floating nest on the sea, and to sing sweetly to its brood; whence the phrase "halcyon days." Actually of course the kingfisher builds its nest in a burrow in the stream or lake bank, and is not at all notable for vocal virtuosity. However, that's just some more of cold-blooded modern science's upsetting of pleasant old fancies.

Driving through a Rainbow

The note on Thoreau's Rainbows in the October issue (page 380) brings to the editor from Mr. C. G. Wates of Edmonton the following interesting incident:

A friend was telling me about a trip through California, and he said that one evening they drove right through the end of a rainbow. Naturally, I was, to say the least, slightly sceptical! Yet, when I asked for exact details, I found that his

statement was strictly correct. "They" consisted of a party of eight, in two cars. They topped a rise in the road and began to descend into a valley. About a mile away was a bridge, and there was a fine rainbow with one end resting on the bridge. My friend was in the second car, and they stopped for a moment to admire the bow. Thus they saw the first car cross the bridge, driving right through the bow. When the second car drove on, it also crossed the bridge, and my friend did not seem to have realized that the bow was no longer there when he reached it. Apparently, the sight of the first car plunging into a riot of colour had impressed him so much that he took it for granted that they also saw the bow as they passed through it. A perfectly natural assumption!

C. A. C.

MEETINGS OF THE SOCIETY

AT EDMONTON

January 8, 1942.—The president called the meeting to order at 8.18 p.m.

Dr. J. W. Campbell announced that the University had agreed to accept the gift of Mr. C. G. Wates' new 12-inch telescope, and to build a small observatory to house it, as well as the 4-inch refracting telescope now belonging to the department of Mathematics.

In his talk on the HANDBOOK Mr. Wates mentioned the noticeable lengthening of afternoons as compared to mornings. The display of the planets Venus, Mars, Saturn, Uranus, Jupiter, and Neptune was pointed out as something brilliant and unusual.

Mr. Wates followed with a short discussion of some of the salient features of the Schmidt camera. He explained the use of the focal ratio as a measure of the speed of any lens or mirror system. For a given-focal-length telescope an increase in size increases speed because (*a*) it collects more light, (*b*) it gives a smaller image, (*c*) the focal ratio is larger. He contrasted 12° in one Schmidt camera without coma, as a coverage compared to less than 1° in many large telescopes. In one case a ratio of F/0. has been obtained as a useful effective value.

Dr. Tuck asked about the times of sunrise published in the newspapers. Dr. Campbell told of his supplying the papers with a universal table good to 1 or 2 minutes over a period of years. For greater accuracy the tedious computations would have to be done every year, and this is not usually necessary.

The main paper was by Mr. J. A. McLean on "The Tides". The birth of the earth-moon system was described, and its dependence on the principle of the

conservation of angular momentum was illustrated by dancers in a waltz. Under early conditions the day equals the month, but these change, both lengthening at different rates. The maximum month of 29 days is past, and we are now back to a 27-day month, though both are still lengthening. They will again reach equality at 1400 hours. This condition is dynamically stable, but solar tides will then become the controlling factor in further changes.

The actual importance of tidal phenomena to mariners, fishermen, and others was briefly discussed.

After the paper there was a demonstration of the conservation of angular momentum on a new table designed to show it, and further illustration by skater whirling.

The meaning of "right ascension" was asked by Mr. Blue and answered by Dr. Gowan. Mr. Smith asked about a planet outside Pluto, and Mr. Keeping explained that the perturbations are not accurate enough for useful prediction.

There were 29 members and visitors present.

E. H. GOWAN, *Hon. Sec.*

February 12, 1942.—The president called the meeting to order at 8.22. The secretary was instructed to cast a ballot each for the election of Mr. F. Voigt, and Mr. R. S. Crosby as members.

The HANDBOOK talk was given by Mr. C. G. Wates. He suggested that more of us might enjoy seeing Venus as a morning star with all clocks advanced. How to find Algol, the winking star, from an identification of the constellation Cassiopeia was explained. Referring to the Schmidt camera, it was stated that the largest is a 48-inch one at Mt. Palomar. There has been considerable improvement in effective power of telescopes by increased speed of photographic plates, particularly in red sensitivity.

Mr. Keeping pointed out an article in *Sky and Telescope* suggesting that predicted times of Algol minima may be wrong by as much as an hour. Another issue refers to an occultation of Mars by the Moon. Photos of this arrived from Manila on Dec. 8, 1941.

Dr. Campbell referred to the destruction of Pulkovo Observatory in the fighting near Leningrad, and told something of its 100-year history. He also read some poems for children by a recent member, Mr. Filmer of Edson, who has been confined to his bed for some time.

The main paper of the evening was by Mr. M. Crockford on the subject "The Origin of the Earth". Various theories were outlined including the Chaos of the Greeks and others, the Nebular Hypothesis of Kant and Laplace, and the Planetesimal Hypothesis of Chamberlin and Moulton. The Stellar or Tidal Hypothesis of Jeans was described in somewhat more detail. Mr. Crockford finished by asking, "What of the future,—what will the death of the earth be like?" There were only two possibilities,—a slow death by cold due to the gradual loss of the sun's heat, or a quick one by heat, which would happen if the sun suddenly flared into a nova.

In the discussion Mr. Keeping mentioned Lyttleton's hypothesis. The sun was one component of a double star. Another passing star made a filament of matter, as in the tidal hypothesis, and took one star of the pair with it. This theory fits the facts of angular momentum.

Dr. Campbell confirmed this and reminded the meeting that Jupiter has 90 per cent. of the angular momentum of the solar system, but has only one-tenth of one per cent. of the total mass.

Mr. Smith mentioned Galileo's difficulty in persuading his contemporaries to examine experimental facts on account of the prevalent belief in seven as a perfect number. He also asked whether ice ages could be caused by a ring of dust from a shattered moon cutting off solar radiation. On probability this seems ruled out by the geological record of at least three ice ages.

There were 34 members and visitors present.

E. H. GOWAN, *Hon. Sec.*

March 12, 1942.— The president called the meeting to order at 8.19 p.m.

There were applications for membership from Miss Jean Barnett, Miss Gwen Clarke, and Mr. George Sloane. The usual motion of acceptance was passed unanimously, being moved by Mr. McLean, seconded by Mr. Blue.

Dr. Campbell gave the HANDBOOK talk. The parade of planets is still spectacular with Jupiter, Mars and Saturn in the evening sky. Mars is moving fastest and will pass the others soon. Venus is brilliant in the morning at 6.30 just above the horizon. The sun passes the vernal equinox on March 21, and the astronomers allow spring its official start. There is a difference between the signs of the zodiac and the constellations from which they take their names. The cause of this in the slow precession of the equinoxes was explained. Whipple's comet is visible in a small telescope just now.

The main paper was by Mr. C. G. Wates, and entitled "Some Limitations of Astronomy." Three great general divisions were treated,—relativity, entropy, and anthropomorphism. Emphasis on definition is very necessary for simple fellows (and for others). The audience was warned that "I think" was understood as implied in many of the statements.

What is space? Is a comprehension of it within the power of the human mind? Is it conceivable, and what does that mean? What is the real relation between mathematics and science? Is space finite but unbounded? Is there instantaneous transmission of gravitational attraction? There is so far no way of knowing.

Time was defined as a catalyst in all physical processes. Energy available to us is due to differences in temperature level. There will be none available at maximum entropy some time in the future. But what of the past? We cannot go back indefinitely.

Is there a meaning and purpose to the universe? Some attempts to supply an answer are always being made. Behavioristic psychology made an attempt to avoid the question by interpreting even the human mind in a purely mechanical

way, but it is now happily discredited. Is the agreement between mathematics and science partly illusory, and are some of our interpretations perhaps wrong or incomplete?

Discussion: Mr. Keeping, Relativity not inherently more difficult than Newton's mechanics. It is just a different way of looking at things. Both start from one law, deductions give agreement in consequences and experiment. The original law may have no apparent reason or cause.

Dr. Campbell, There is difficulty in visualising what Einstein started with. Illustration of Michelson-Morley experiment by time of travel across and back or up and down a stream. Applied to find our velocity in the ether giving a negative result. This is the basis of the special theory in comparing distances and times between fixed and moving observers.

Mr. Smith, Man forms and changes his picture with improved methods of observation and measurement.

Dr. Gowan, Sometime would try to make a model, after the rubber shortage is over.

There were 33 members and visitors present.

E. H. GOWAN, *Hon. Sec.*

April 9, 1942.—The president called the meeting to order at 8.15 p.m.

The president informed the meeting of the sudden death of Mrs. J. G. (Delle) Taylor, one of the charter members of the Edmonton Centre. Tribute to her memory was recorded by those present standing for a moment of silence.

On the motion of Dr. Campbell and Professor Keeping it was agreed that a letter be sent to Mr. J. G. Taylor by the secretary expressing sympathy of the members in the death of his wife. It was noted by Dr. Campbell that Mr. Taylor was a past president of the Edmonton Centre. It was also agreed, on the motion of Mr. Higginbotham and Dr. Tuck, that the treasurer arrange that flowers be sent to commitment service for Mrs. Taylor to be held in St. Thomas, Ontario.

The HANDBOOK talk was given by Mr. C. G. Wates.

The paper of the evening was presented by Professor E. S. Keeping on the subject "Asteroids."

The speaker first of all described Bode's Law (1772) as a means for recording the distances of the planets from the sun, a numbering scheme which fitted the known planets remarkably well.

Good agreement with the scheme was had with Uranus (1781), but the later discoveries of Neptune and Pluto showed that the so-called law was a numbering scheme having no known physical significance and breaking down badly in the case of Pluto.

The agreement of Uranus with the "law" and the fact that a gap in the law existed between Mars and Jupiter led to the hypothesis of an unknown planet at a distance 2.8 times the distance of sun to earth. In 1801 Piazzi accidentally discovered Ceres, the first of the many minor planets or asteroids to be dis-

covered with orbits around the sun at a mean fundamental distance of about the required 2.8.

The speaker dealt with the speculations regarding the origin of these hundreds of asteroids, none of which has given satisfaction.

The modern means of location of the asteroids by photography was illustrated with a slide showing three asteroid trails. The problem of orbit analysis was also touched upon, it being noted that of the 2799 located in the period 1930-1939, only 373 proved to be new. The vast number of these "friends and relations" of the solar system has reduced them for the most part from stately Greek Goddesses to items in a numerical catalogue.

The speaker dealt with the size, constitution and brightness of the asteroids, the largest being Ceres (dia. 480 mi.) and the brightest being Vesta. The total mass of the asteroids, including those yet undiscovered, is not likely to exceed the mass of the moon.

The effect of Jupiter upon these small bodies was considered and the orbits of the odd dozen asteroids (the Trojans) markedly affected were described.

The remainder of this interesting and informative paper was devoted to the asteroid Eros (1898, dia. 18 mi.) and its significance. The orbit of Eros is extreme, in that the orbit is near to that of the earth. The last opposition occurred in 1931 when Eros was 16,000,000 mi. from the earth. It is this close approach of Eros that makes it of great importance, for the reason that Eros provides astronomers with the best means of measuring the distance of the earth from the sun. Professor Keeping described in simple terms the essential steps in making the measurement and then related the success of the observations made during the opposition of 1931. Twenty observatories all over the world coöperated in this project under the directions of the Astronomer Royal and the results were highly consistent with a distance of 93,005,000 mi. being obtained (uncertainty about 9,000 mi.).

In the discussion that followed the following points were noted: The retrograde moons of Jupiter, are they asteroids? The reason for Vesta's brightness. The relation to the Planetesimal Theory. The determinants of an orbit. Mr. Leaver also raised a separate question regarding the original size of Jupiter and the ultimate size of the sun, (the question arising from his reading Gamow's "Birth and Death of the Sun."

There were 27 members and visitors present.

A. J. Cook for *Hon. Sec.*

May 14, 1942.—The president called the meeting to order at 8.19 p.m.

The Handbook talk was given by Mr. C. G. Wates. The audience was asked to detect mistakes in several statements made. The reasons for an increase of temperature after June 21 (when the sun is farthest north) were given. Solar eclipses in August and September will not be visible in Canada. The moon is in perigee on May 30 and will be eclipsed August 25. Venus is now a morning

star again. Diagrams of the different apparent sizes of the moon at apogee and perigee were shown on the board. In the lantern were shown photographs of a telescope made by a B.C. amateur.

The main paper was by Dr. Scott of the Physics Department on the subject "Universal Gravitation." The first formal statement occurs in Newton's "Principia." The ancients wanted to predict the positions of the stars, but had difficulty with the planets or wandering stars. Their retrograde motion was illustrated by a sketch. Ancient work was based on two fundamental principles, (1) the earth is stationary, (2) all heavenly bodies move with uniform circular motion. Ptolemy tried to fit the facts with these principles by using epicycles up to nine. The type of argument used was illustrated by Bacon's discussion of the number of teeth in a horse's mouth. Kepler's work on Tycho Brahe's observations yielded his three laws in thirty years of labour. There was a shift in question from how to why with the work of Galileo, upon which Newton's laws are built. The speaker reconstructed Newton's thoughts after the fall of the significant apple. Newton made his calculations and got a check on the moon, but published his result only after proving that the force of a sphere was the same as that due to an equal mass concentrated at a point. The constant G in Newton's equation was evaluated by Cavendish in 1798. From this law equal acceleration of all falling bodies is expected, and this was shown experimentally by a penny and a feather in a vacuum. The falsity of Aristotle's reasoning on this subject was illustrated.

Various applications of universal gravitation were discussed, including: the velocity of escape and the gases present on the planets, tides and their effect in slowing down the earth, meteorites, craters in Arabia and a story of great fire from heaven, the discovery of Ceres and the Gauss method of finding the orbit from thre observations, perturbations and the discovery of Neptune, comets and Jupiter's effect in changing parabolic to elliptic orbits, the masses of the stars and their luminosity, the wavy motion of Sirius and the consequent calculation of the companion's high density (checked by the spectroscope), the predictions of relativity about Mercury and about the bending of light passing the sun. The question of which theory is better is meaningless. They are different ways of looking at the same thing.

The following points were brought out in the discussion: the atomic theory of dense matter, Galileo's marble in a bowl leading to the first law, straight line and geodesic in practice, speed of gravitation cannot be measured because matter cannot be created or destroyed, levitation tricks, same laws for projectiles neglecting air resistance, Galileo's difficulties with the church, it is not gravity that clusters small particles on a microscope slide or that produces auroral patterns,—other forces are involved.

The application for membership of Mr. I. M. Jones was accepted on the motion of Mr. Willoughby and Mr. Blue.

A recent "Pelican" book "The Stars in their Courses" by Jeans was recommended to the Centre.

It was moved by Mr. Smith and seconded by Mr. Stockwell that the Executive consider having a large membership certificate suitable for framing. Carried. Mr. Smith presented a proposed design.

There were 30 members and visitors present.

E. H. GOWAN, *Hon. Sec.*

AT TORONTO

March 31, 1942.—The Society met in the McLennan Laboratory, University of Toronto, at 8.00 p.m., Dr. D. W. Best in the chair.

Mr. H. W. Barker addressed the Society on "Astronomical Errors in Literature." A condensation of the paper follows:

Making friends of the stars is a restful occupation for, no matter how excited and perturbed we may be, the host of heaven moves on its course in calm and dignified silence, never hurried and never worried. The gaining of some knowledge of the ordinary everyday facts concerning the universe should be encouraged as much as possible. Astronomy is a subject which can never be finished, and judging by some of the absurd statements which we sometimes come across in books by prominent authors and more frequently by lesser lights, or which we hear from platform or pulpit, there is even among educated men and women widespread ignorance of many of the elementary facts concerning the heavenly bodies.

The confusing of planets and stars is one of the most common errors. A little knowledge of astronomy, too, would dissipate many of the superstitions which are implicitly believed in by many people, for example, that the tilt of the crescent moon indicates the approach of wet or dry weather, or that the bear and its shadow indicates a late or early spring. The greatest superstition, however, is in the realm of astrology whose disciples teach that the stars affect human life and destiny. Guesses, all of them!

There are occasional misstatements found in high-class as well as in mediocre literature. And, speaking of guesses, there is the famous case of Dean Swift in "Gulliver's Travels" describing the two moons of Mars. He gives their sizes and their periods of revolution—mere guesses— but after all, they were verified as to the number, and approximately right as to the periods when the moons were discovered 132 years after Swift died.

Poets and prose writers are not always as careful as was Lord Tennyson. He made many references to the stars and planets and it is said that he always consulted the Astronomer Royal if he was in doubt. At least one passage however has been made open to question by recent findings. That is where he refers to binaries as: 'Those double stars whereof the one more bright is circled by the other.' It is now evident that sometimes the brighter star revolves around the one less brilliant.

Shelley changed his "witch of Atlas" into a vapour, then into a cloud. We do not object to this, but we are puzzled when the next reincarnation changes her 'into a meteor such as caper on hill-tops when the moon is in a fit.' It certain-

ly would be a caper for meteors and the moon to cut up in such a fashion! The next stage of existence of this beautiful 'witch' takes us to an even more uncertain place. . . . 'Then into one of those mysterious stars, which hide themselves between the earth and Mars.' If Shelley referred to the asteroids he overlooked the fact that they are between Mars and Jupiter.

Among those errors which are obvious is one familiar example often referred to from Coleridge's "Ancient Mariner." The poet speaks of: 'The horned moon with one bright star within its nether tip,' which is, of course, a physical impossibility. E. A. Powell in his book, "Free Lance," falls into the same error when he says: 'In the eastern sky, in the direction of Baghdad, hung a crescent moon with a star between its horns.' H. Rider Haggard in "King Solomon's Mines" tells how a party of white men eluded a band of savages by taking advantage of the darkness caused by a total eclipse of the sun which lasted 'for more than an hour.' Some eclipse! Some darkness! There never can be a total eclipse which lasts more than about seven minutes and even then there is not total darkness. On the evening of the same day as the eclipse, the judge-novelist continues, the 'light of the full moon' helped them on their way. In another place he refers to a *waning* crescent moon being seen in the early evening—a phenomenon which is also quite impossible.

Poetic licence covers a multitude of sins and Charles Wolfe, in his stirring poem "The Burial of Sir John Moore" may be forgiven for having the burial take place 'by the struggling moon-beams' misty light.' The date was January 16, 1809, and the moon was new at one o'clock that morning and therefore invisible. Perhaps the poet himself had doubts for he added the words: 'And the lantern dimly burning.' Another case involving the moon is the story told of Abraham Lincoln. He was defending a man who was being tried for murder and the whole case rested on the evidence of one man who swore that 'the moon suddenly disappeared behind a cloud.' Lincoln was able to prove that there was no moon visible that night and his client was acquitted.

Gene Stratton Porter, whose books are so interesting for young people, makes the moon move from place to place to suit any purpose. In "The Harvester" she places the young moon behind a tree-top in the west—quite properly—but later the same night 'it rises above the trees and floods the whole country with light.' Another author tells us 'it was midnight and the new moon was just rising in the east,' while in the *Geographic Magazine* for January, 1921, an author tells us 'a young moon rode clear overhead.' Charles Dickens in "Hard Times" describes the sufferings of Stephen Blackpool as he languished at the bottom of a shaft—his only comfort coming from a star which continued to shine down the shaft hour by hour. Lew Wallace in "Ben Hur" tells us that Sheik Ilderman's race horses were named after certain stars. This all happened at the beginning of the Christian era, but these stars were not given names until several centuries later—Mira, for instance, nearly 1600 years.

Thomas Carlyle, that cynical old critic, makes some rather surprising statements. In his "French Revolution," describing events on the night of August 9, 1792, he says: 'The night . . . is beautiful and calm. Orion and the Pleiades

glitter down quite serene.' Yet neither of these constellations is in evidence on an August evening. In another place he wrote: 'Overhead, as always, the Great Bear is turning so quiet round Boötes.' We do not wonder that he lamented (if it was Carlyle who uttered this lament): 'Why didn't someone teach me the constellations and make me at home with the starry heavens which are always overhead and which I do not half know.'

Dr. Helen S. Hogg presented the tenth in a series of papers on "Explorations in Clusters and Nebulae." Dealing with supernovae, she said they "are probably the rarest and most spectacular phenomena observable in the universe." Supernovae are stars which flare up overnight in our own and in some of the external galaxies, on the average of once in every six centuries in each galaxy. They may blaze out suddenly to a luminosity 100,000,000 times that of the sun. In a few days they often reach the brightness of the whole galaxy in which they are embedded and after pouring out tremendous energy for a short time they fade away. In comparison with supernovae, the upper limit of luminosity for a stable star is about 60,000 times that of the sun.

Normal novae probably occur at the rate of ten or twenty a year in our own galaxy and are observable in some of the external galaxies, but their upper limit of luminosity probably never exceeds 100,000 suns. The normal type of nova occurs when a star becomes unstable and blows off its outer portions which form an envelope around it. Such an envelope has been observed to expand with a velocity of 1000 miles a second; for example, Nova Aquilae 1918, one of the half-dozen bright ones of the 20th century. This nova increased in brightness from magnitude 11 to the first magnitude in two days.

Supernovae, on the other hand, are such incredible catastrophes that it was years before astronomers could accept the evidence which was indicated when the first such phenomenon was recorded in M31, the Great Andromeda Nebula, in 1885. There was dispute for many years after as to whether the object could possibly be in the nebula itself. It reached an apparent magnitude of 7.2; one-tenth of the brightness of the whole nebula. More than 40 supernovae have been recorded in 36 stellar systems since that time; 22 of them since 1937 by an intensive search by Zwicky and his associates at Mount Palomar, using a Schmidt camera.

Supernovae occur in all types of extra-galactic nebulae and can be classified in two groups. Group I comprises supernovae whose maximum luminosity is of the order of 100,000,000 suns. The brightest on record is one found by Zwicky in 1937 in the nebula I.C. 4182 (3,000,000 light-years distant) which reached a luminosity of 600 million suns, 100 times brighter than the whole nebula. This star radiated in one day as much photographic energy as the sun has radiated in one-and-a-half-million years. The spectra of supernovae in Group I have not been interpreted. The energy may be due to annihilation of matter by atomic reaction at a rate of 2×10^{18} tons a second. Comparison for the sun would be about 4,000,000 tons a second. Group II of the supernovae are more similar to normal novae except they are much brighter, the maximum being about

10,000,000 suns. They are characterized by bumps on the descending branch of the light curve. It is possible that stars will be found which are intermediate between this group and normal novae. The spectra have recognized features such as bright bands.

Recent research has shown that two early observed novae in our own stellar system were really supernovae. One is Nova Cassiopeiae 1572, observed by Tycho Brahe as bright as Venus and visible in full daylight. This star has not been identified on photographs. The second supernova in our galaxy is Nova Tauri 1054 which the Chinese recorded as a daylight star. The date was determined by a study of the rate of expansion of the gaseous envelope and was later identified in ancient Chinese records. The nebula around this star, known as the Crab Nebula, has been expanding since 1054 and is undoubtedly the remains of the supernova. At a distance from us of 5000 light-years, the nova at maximum was equal to 300 million suns. This star is now identified by Minkowski on photographs as a highly collapsed white dwarf star.

Collisions between stars must be too rare to account for the frequency of ordinary novae. Such collisions cannot occur more frequently than about once in 1000 years in any galaxy. However, they may occur frequently enough to account for supernovae, Dr. Hogg said.

FREDERIC L. TROYER, *Recorder.*

April 14, 1942.—The Society met in the McLennan Laboratory, University of Toronto, at 8.00 p.m., Miss Ruth J. Northcott, Vice-Chairman, presiding.

The following persons were elected members of the Society:

Mr. Carl C. Akerfeldt, 150 Audrey Avenue, Toronto.
Mr. Stanley E. Hathway, 132 Virginia Avenue, Toronto.
Mr. Homer Oullette, Millbrook, Ont.

Dr. D. W. Best then gave a paper on "Messages From the Stars—Spectroscopy." The only message that reaches us from the stars is contained in their light. Dark bands in the spectrum of sunlight were first noticed by Wollaston in 1802. These were further studied by Fraunhofer in 1814 and he assigned letters to identify the principal dark lines in the solar spectrum. Foucault in 1849 superimposed the spectrum of the sun on that of sodium heated in a carbon arc and found that the D line in the solar spectrum coincided exactly with the bright line of sodium in the emission spectrum. Identification of the H and K lines by Kirchhoff followed. Sir William Huggins pursued the study of spectra of many stars, in addition to the sun, and his work led to the finding that a common chemistry seemed to exist all through the visible universe. It was like the finding of a Rosetta Stone, but reading the messages from the stars was not so easy as deciphering the Egyptian hieroglyphics.

Dr. Best went on to describe and explain the use of the various instruments used in the laboratory and astronomical spectroscopy—the common prism, spectrograph, prismatic slit spectroscope, grating, spectroheliograph, photometer, photoelectric cell, volometer, pyrheliometer and stellar interferometer. The

power of the spectroscope depends on the dispersion of light and many of the phenomena met can be explained only by regarding light as wave motion. There is hardly a single characteristic of the spectra of the elements that cannot be altered, and the variation in the appearance of the lines and other features provide information concerning the physical condition of the element under study, such as temperature, pressure, electrical excitation, and so forth.

An emission (bright line) spectrum is given by self-luminous sources, while an absorption (dark line) spectrum from a star tells us what part of the light has been absorbed by a surrounding atmosphere. Giving an explanation of the Doppler effect and its use in astronomical study, Dr. Best pointed out that compression of waves as indicated by a shortening of the wave-length indicates approach of an object, such as a distant nebula. In such a case there is a shift of the lines in the stellar spectrum toward the violet end of the spectrum. On the other hand, if the object is receding, the shift is toward the red as the wave-length is increased. The Doppler principle is also applied in the study of rotation of the sun and planets. The amount of the shift toward either end of the spectrum indicates the velocity.

Dr. Helen S. Hogg then presented the eleventh and final paper in a series on "Explorations in Clusters and Nebulae." The paper, "A Survey of the Physical Universe," summarized the content of the ten previous short lectures in the series.

Even the nearest star to the sun is so far away from us that existing telescopes could not detect a planet going around it. Ours is the only solar system we know of, but there may be others. With the single exception of the hazy patch which is the Great Nebula in the constellation Andromeda, every object to be seen with the unaided eye in the heavens (as seen from the northern hemisphere) is part of our own galaxy which comprises billions of stars. Some are very tenuous, others very dense. They range in diameter from 30,000 to millions of miles in diameter, but even the small stars have about as much matter in them as the large ones. Their temperatures range from 1200° up to 100,000° at their surfaces.

Our own galaxy, a flattened system of billions of stars, has a diameter of about 100,000 light-years. The sun is probably two-thirds of the way from the centre to the edge but heavy gas-clouds make very exact measurements difficult. Once every 200-million years the sun completes a journey around the distant centre of the galaxy which lies in the direction of the constellation Sagittarius. Probably more than 90 per cent. of what is believed to be the massive central nucleus of the galaxy is cut off from observation by dense clouds of gas. The stars in our galaxy are spaced on an average of four or five light-years apart; a pinhead every 15 miles would give an idea of the scale. Because of these distances chances of collision between stars are very rare. In addition to normal stars our galaxy abounds in variable stars, double stars and huge gaseous nebulae or clouds, both bright and dark. Remarkable clusters of stars, some containing dozens, some thousands, border our system.

Beyond our own galaxy lie the external galaxies, also systems of billions of stars comparable in size and shape to our own galaxy. In them occasionally are

seen remarkable stars, called supernovae, which flare up and for a few days equal in light-output the millions of stars in the galaxy surrounding them. A hundred-million of these external galaxies lie within the reach of the 100-inch telescope and many more are hidden by the central nucleus of our own galaxy. The only such external galaxy visible to the naked eye in our hemisphere is the "lucid spot" in the constellation Andromeda at a distance of about 700,000 light-years. A group of nearby galaxies, including the Andromeda Nebula are actually companions of our galaxy in space and form a physical family with it. There may be a dozen members of this group and they are near enough to be resolved into stars and studied in detail.

In all directions lie thousands and thousands of fainter nebulae. These show a remarkable phenomenon known as the velocity-distance relationship. It is an observed fact that the lines of the spectra of the distant nebulae are all shifted to the red. If interpreted as a velocity shift, the velocity of recession increases 100 miles per second for every million light-years increase in distance from us. The greatest distance yet measured is about 250-million light-years for a nebula with a velocity of 26,000 miles a second. The interpretation of this red shift in the spectra is still in doubt, but the existing observations, which are made at the extreme limit of the 100-inch telescope, cast some doubt that it is an actual recession of the nebulae and indicate that it may be due to some unrecognized physical principle. If the red shifts are due to actual recession, we have a universe in which the velocities of the nebulae increase systematically with distance in all directions. In this case the cosmological principle is violated. The universe, on this assumption, is too small, young and dense. Counts with the 100-inch telescope at the limit of observation do not indicate any "dimming" factor and astronomers are being forced to conclude that the red shift is not due to expansion of the universe. If these red shifts are not due to actual recession, we have a sensibly infinite and homogenous universe with the observable region an insignificant fraction of the whole, Dr. Hogg said.

Miss Northcott announced that the executive was making plans for summer program of observational meetings.

FREDERIC L. TROYER, *Recorder*

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1890-1942

The Society was incorporated in 1890 under the name of The Astronomical and Physical Society of Toronto, and assumed its present name in 1903.

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal, P.Q.; Ottawa, Toronto, Hamilton and London, Ontario.; Winnipeg, Man.; Edmonton, Alta.; Vancouver and Victoria, B.C. As well as about 700 members of these Canadian Centres, there are over 200 members not attached to any Centre, mostly resident in other nations, while some 300 additional institutions or persons are on the regular mailing list for our publications.

The Society publishes a monthly JOURNAL containing about 500 pages and a yearly OBSERVER'S HANDBOOK of 80 pages. Single copies of the JOURNAL or HANDBOOK are 25 cents, postpaid. In quantities of 10 or more copies, the price is 20 cents a copy.

Membership is open to anyone interested in astronomy. Annual dues, $2.00; life membership, $25.00. Publications are sent free to all members or may be subscribed for separately. Applications for membership or publications may be made to the General Secretary, 198 College St., Toronto.

The Society has for Sale:

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The Physical State of the Upper Atmosphere, (revised 1941) by B. Haurwitz, 96 pages; Price 75 cents postpaid.

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